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Dean

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[45] **Date of Patent: Jun. 27, 2000**

[54] **HORIZONTAL FLOW GENERATION SYSTEM**

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[73] Assignee: **Chemineer, Inc.**, Dayton, Ohio

[21] Appl. No.: **09/146,686**

[22] Filed: **Sep. 3, 1998**

Related U.S. Application Data

[63] Continuation-in-part of application No. 08/726,680, Oct. 7, 1996, Pat. No. 5,803,601.

[51] **Int. Cl.**[7] **B01F 3/04**; B01F 5/12; B01D 45/00

[52] **U.S. Cl.** **366/101**; 366/102; 366/137; 366/270; 261/93; 210/194; 210/219

[58] **Field of Search** 366/101, 107, 366/102, 137, 150.1, 158.5, 159.1, 163.2, 164.1, 164.4, 164.5, 181.5, 182.1, 182.3, 174.1, 241, 244–249, 262–265, 331; 261/119.1, 93, 36.1, 121.1, 124; 210/194, 219, 926, 221.2, 221; 415/208.1, 211.1, 151

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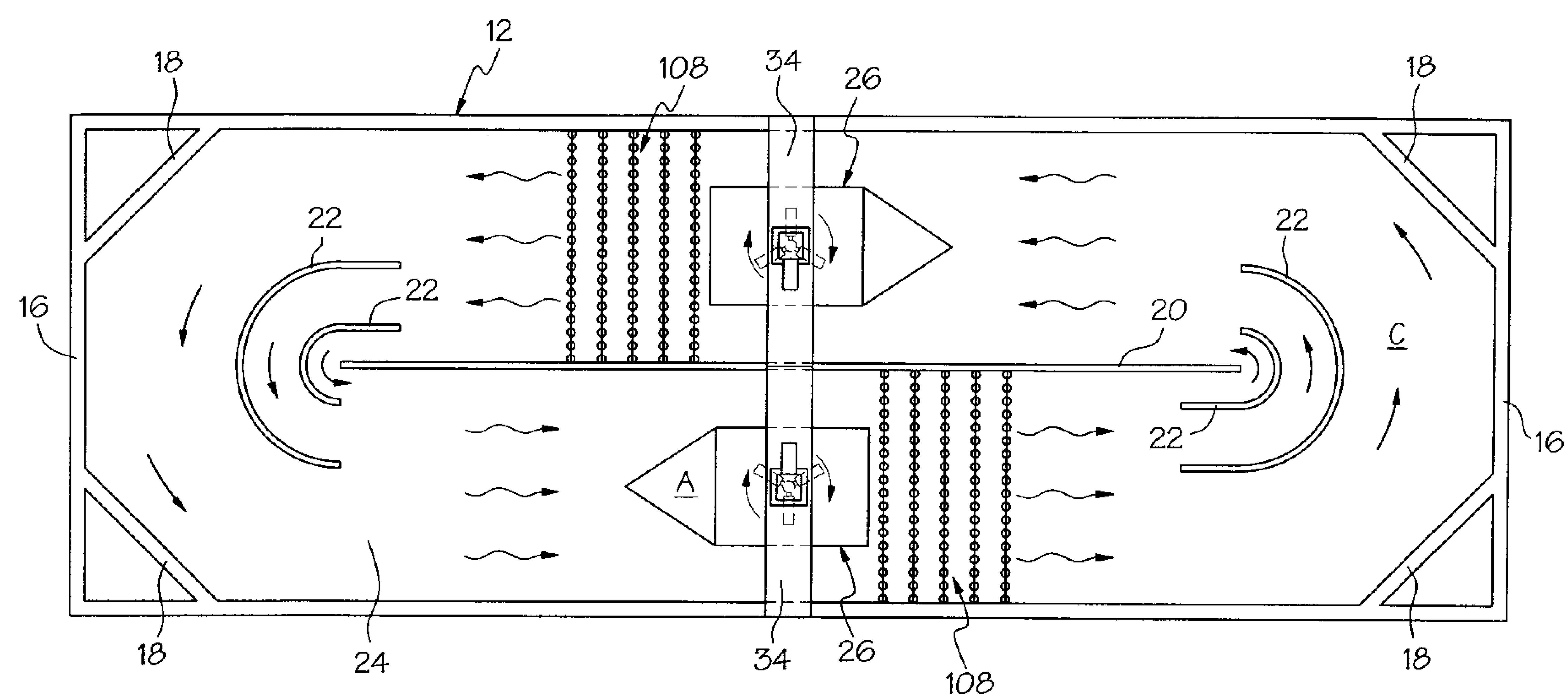
Primary Examiner—Tony G. Soohoo

Attorney, Agent, or Firm—Thompson Hine & Flory LLP

[57] **ABSTRACT**

A fluid mixing system including a liquid mixing device and method for generating and maintaining a substantially uniform, horizontal velocity profile in a liquid circulation system, such as a plug flow reactor, which requires less horsepower than conventional liquid mixing systems without losing mixing effectiveness. The liquid mixing device employs a top-entry, vertically-oriented impeller and a housing that directs the pumped flow in a generally horizontal direction. The liquid mixing module may be positioned in close proximity to an aeration source within a channel.

15 Claims, 11 Drawing Sheets



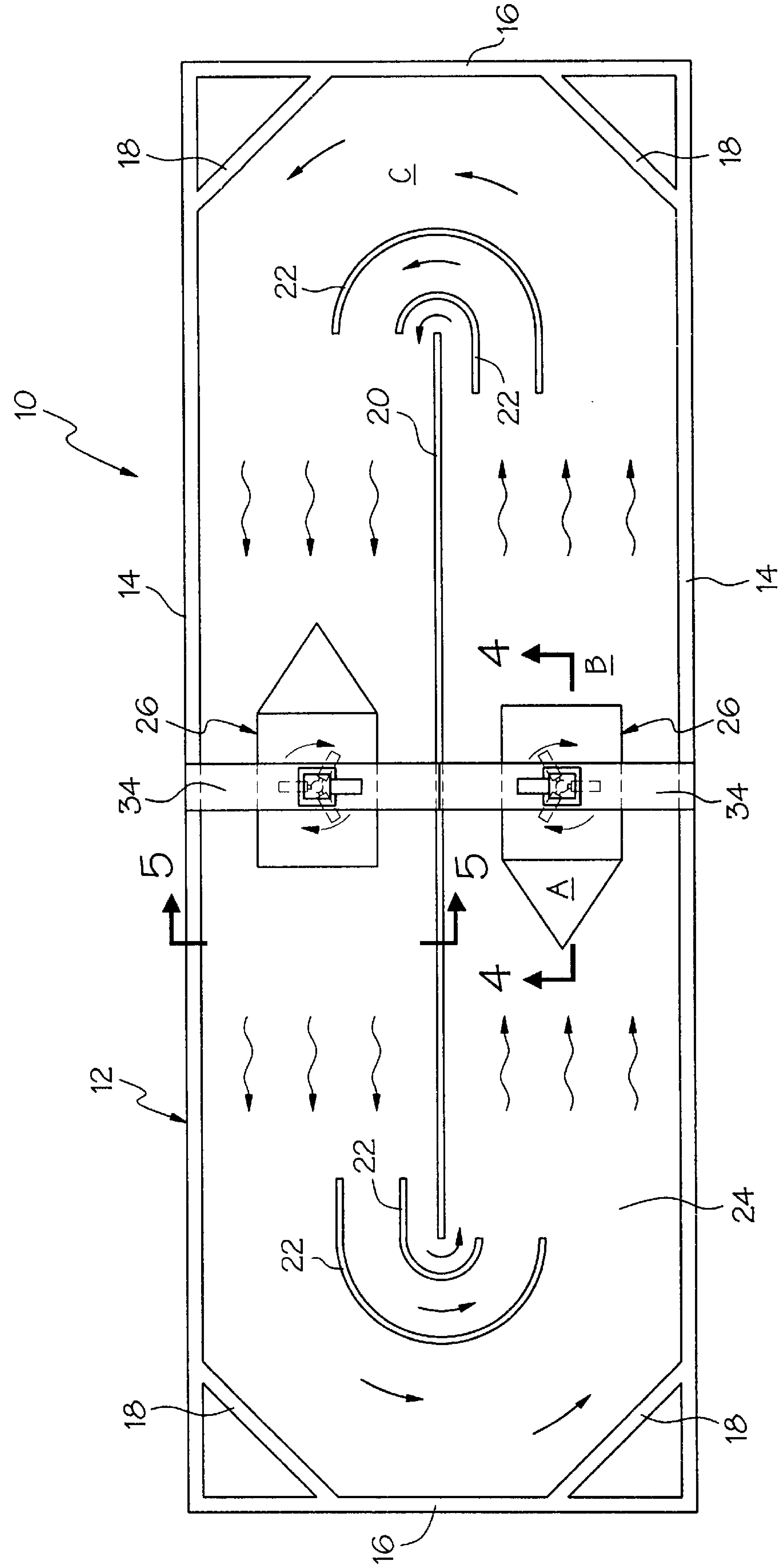
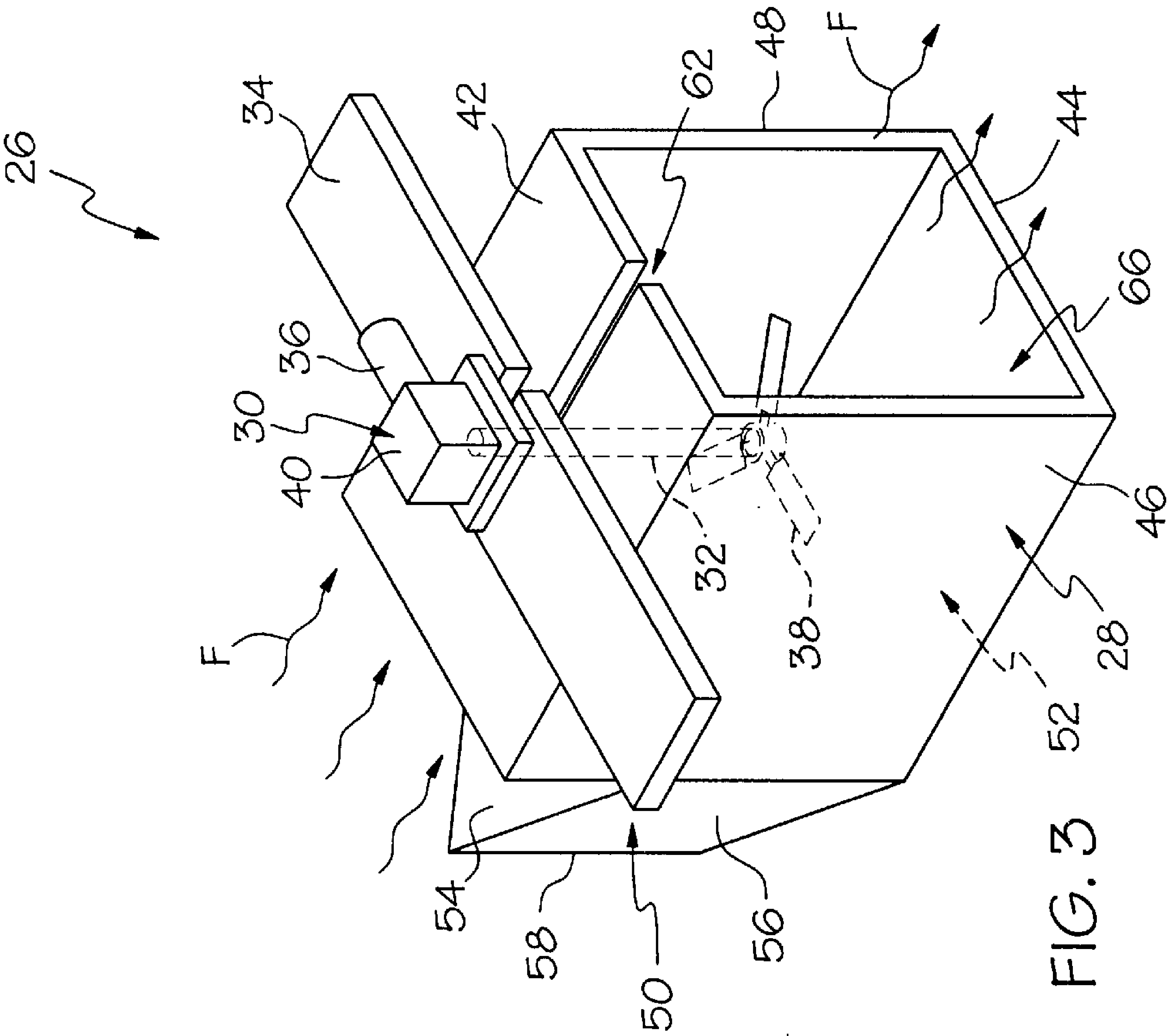


FIG. 1


26
34
42
62
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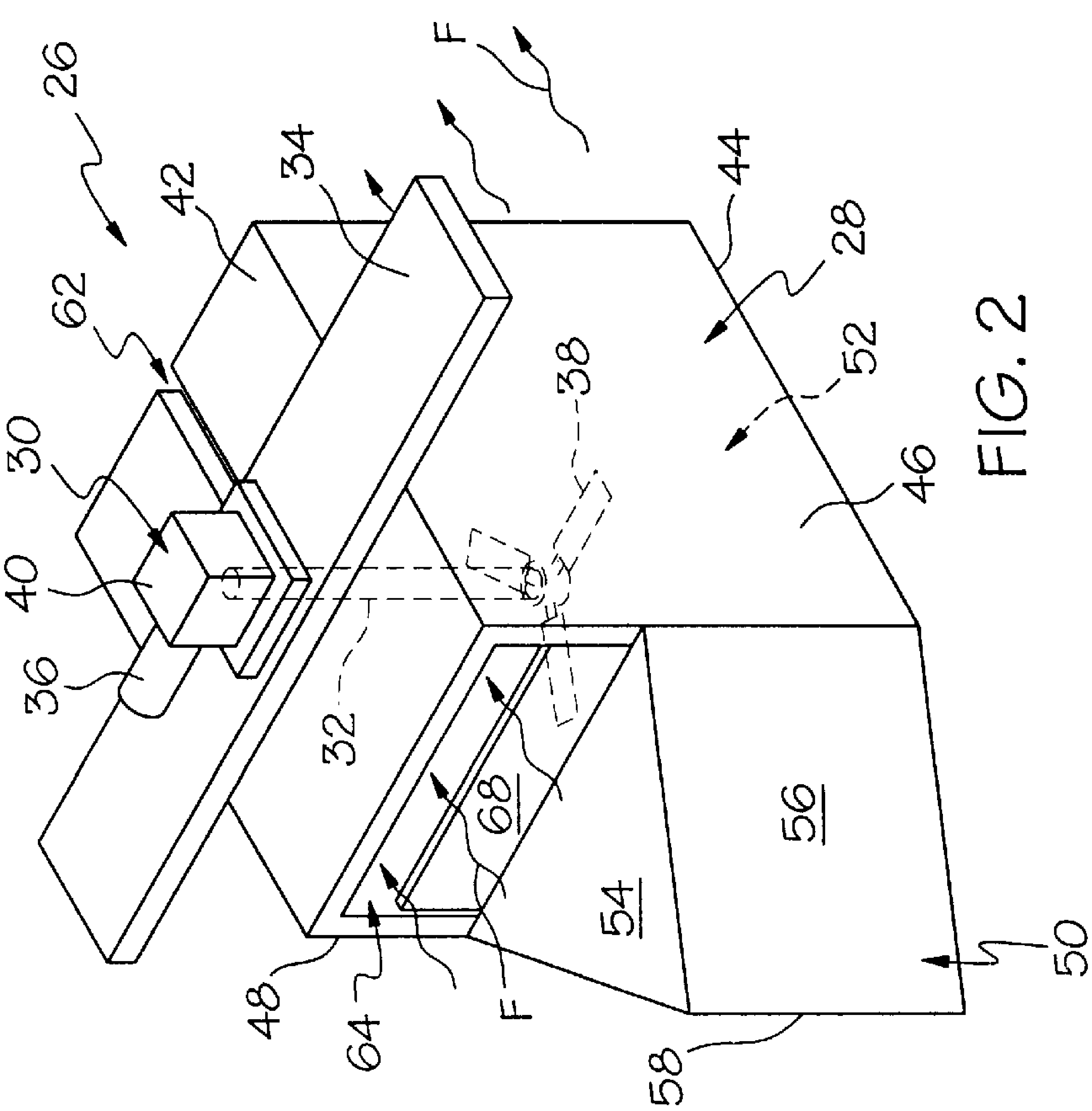
44
66
36
30
40
32
38
46
28
52
F
54
58
50
56

FIG. 3


26
F
42
34
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F
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50

FIG. 2

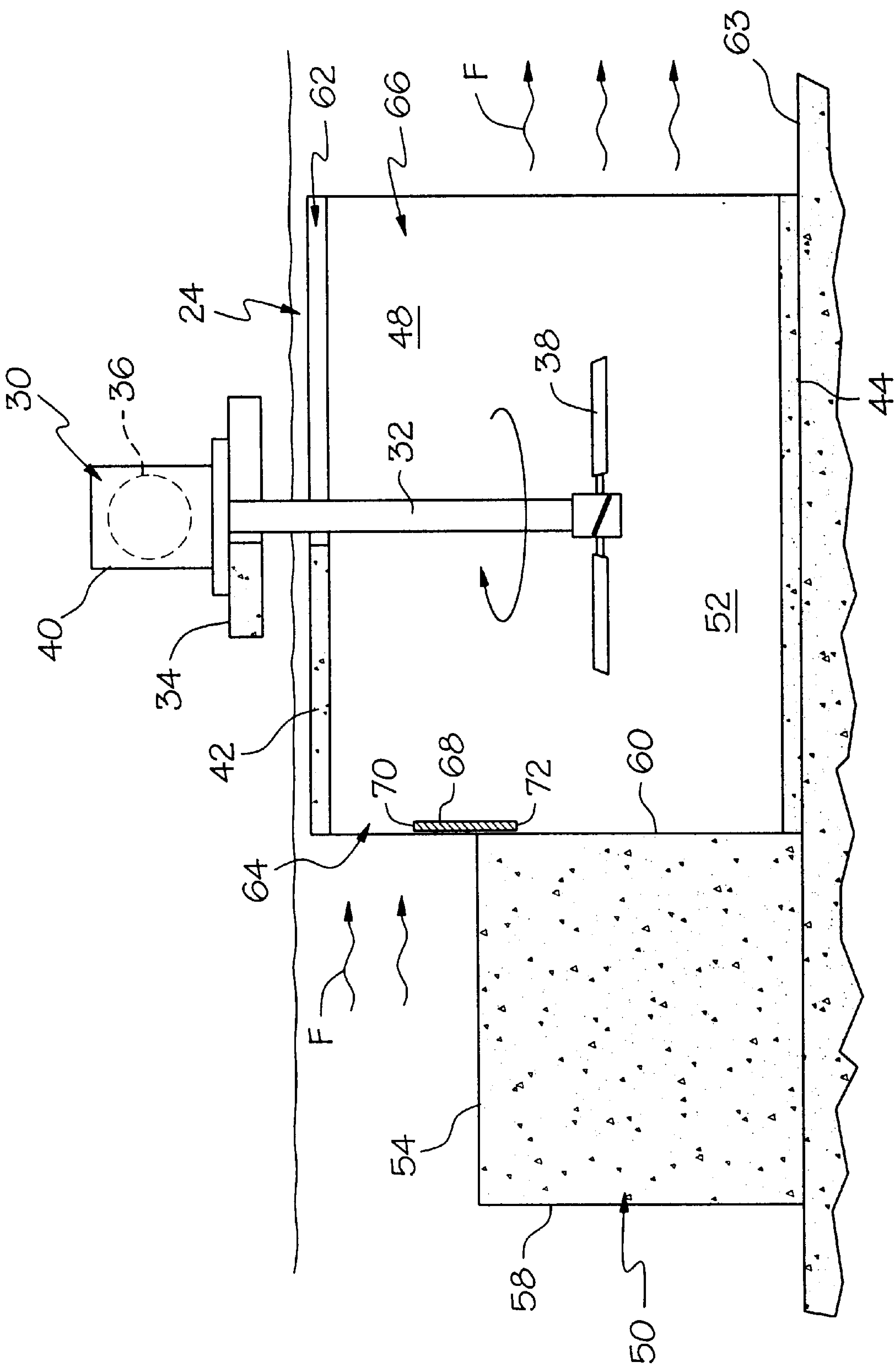


FIG. 4

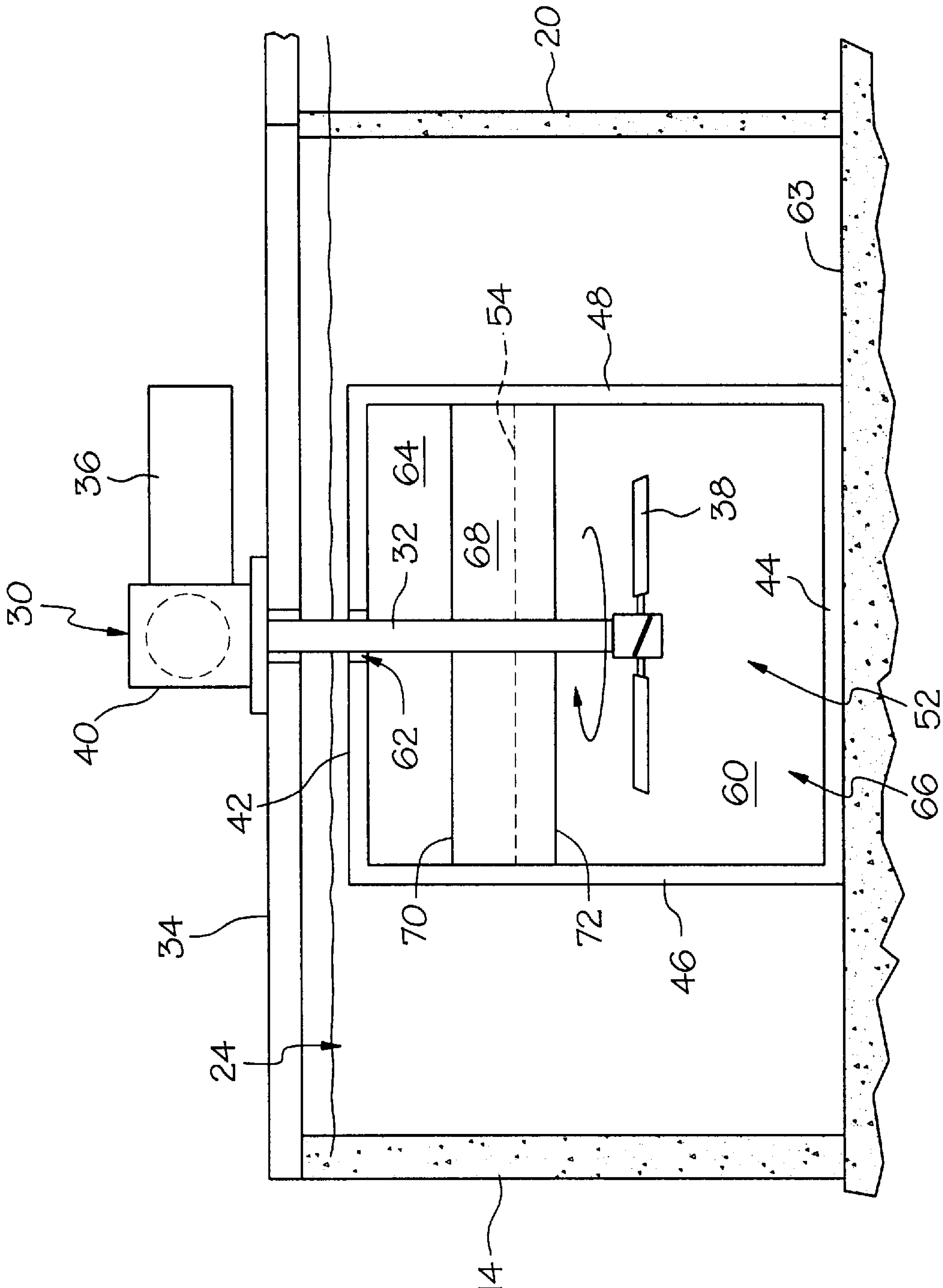


FIG. 5

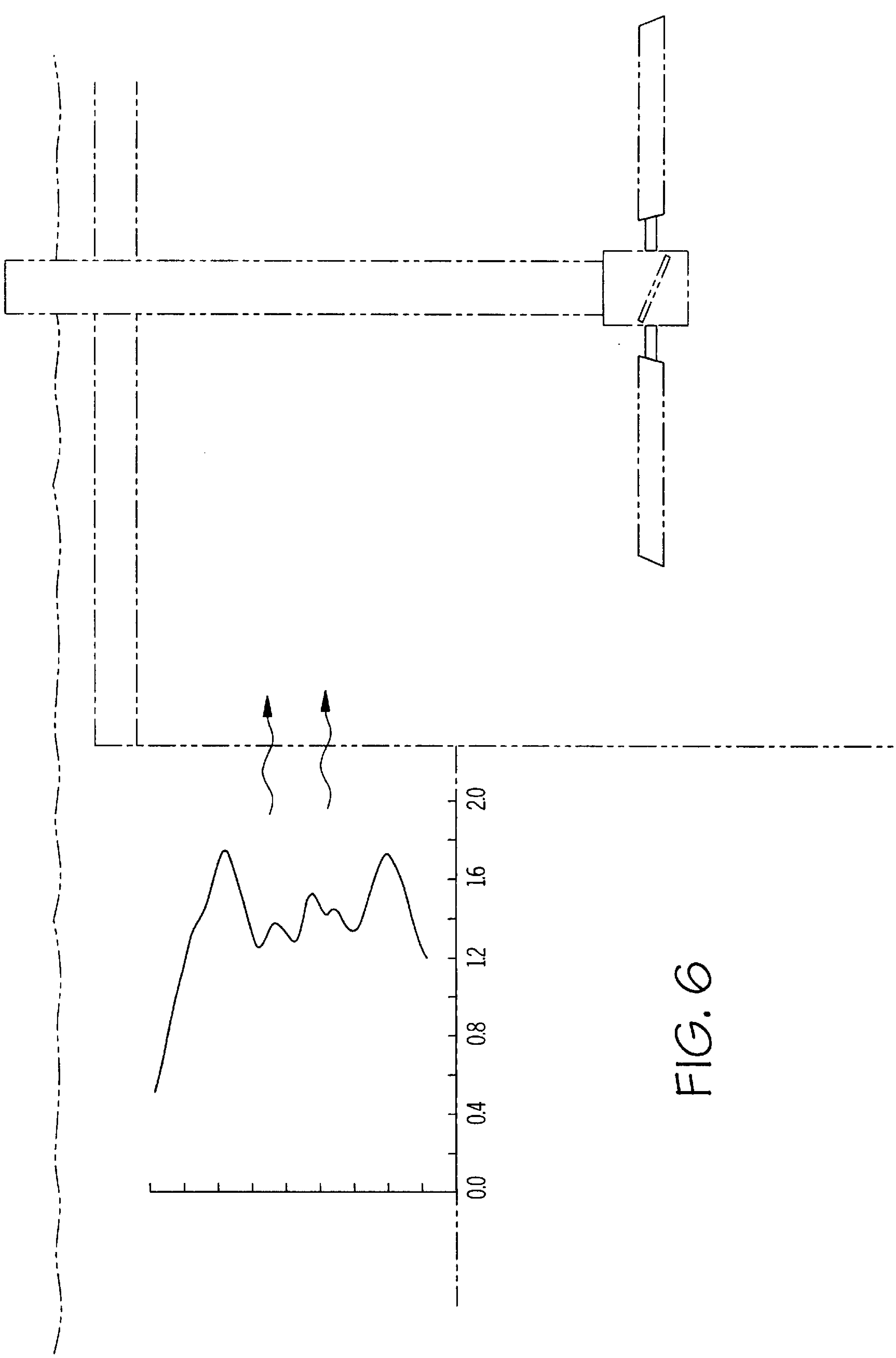
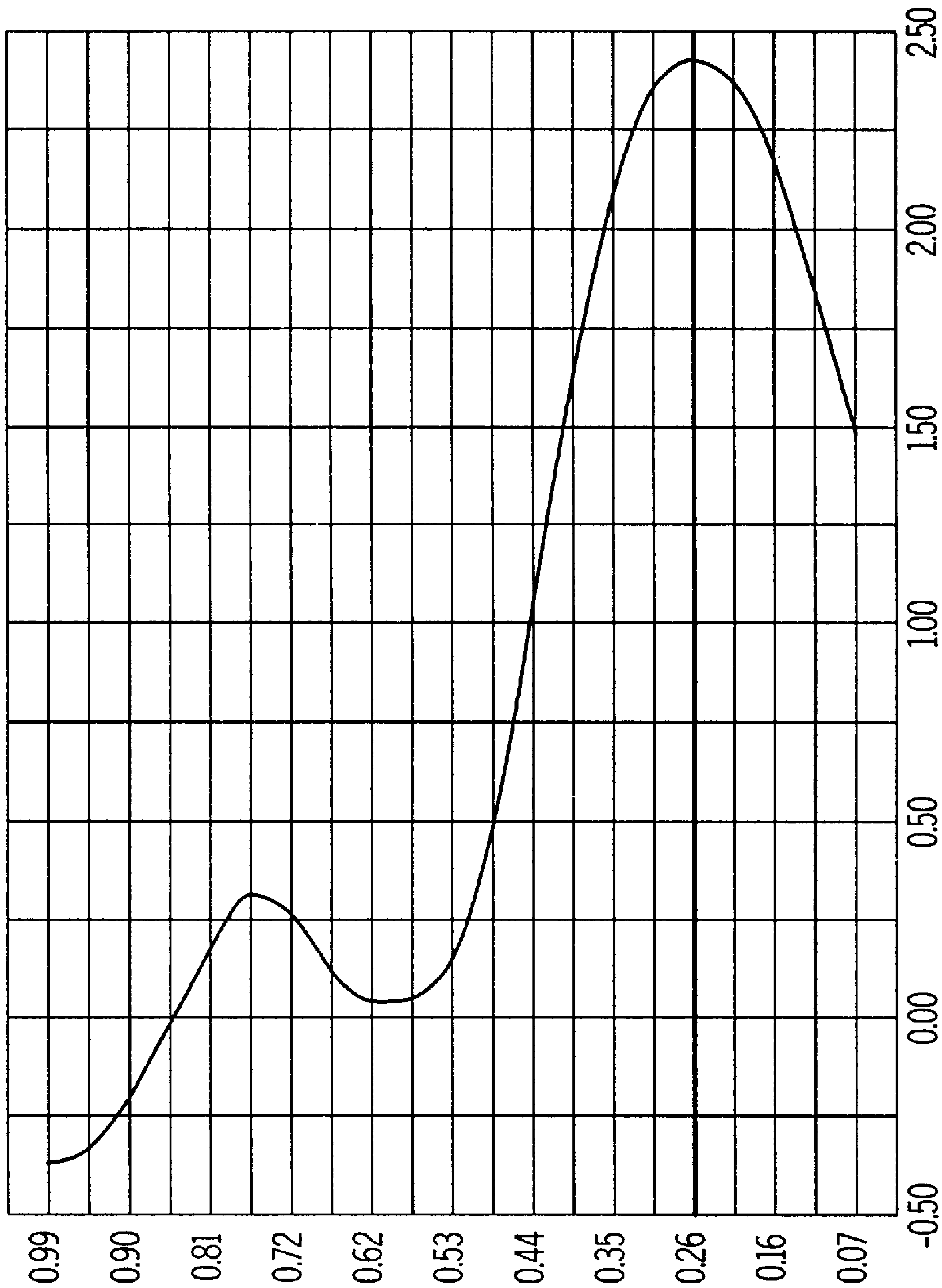


FIG. 6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0.72
0.62
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0.44
0.35
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0.50
1.00
1.50
2.00
2.50

FIG. 7

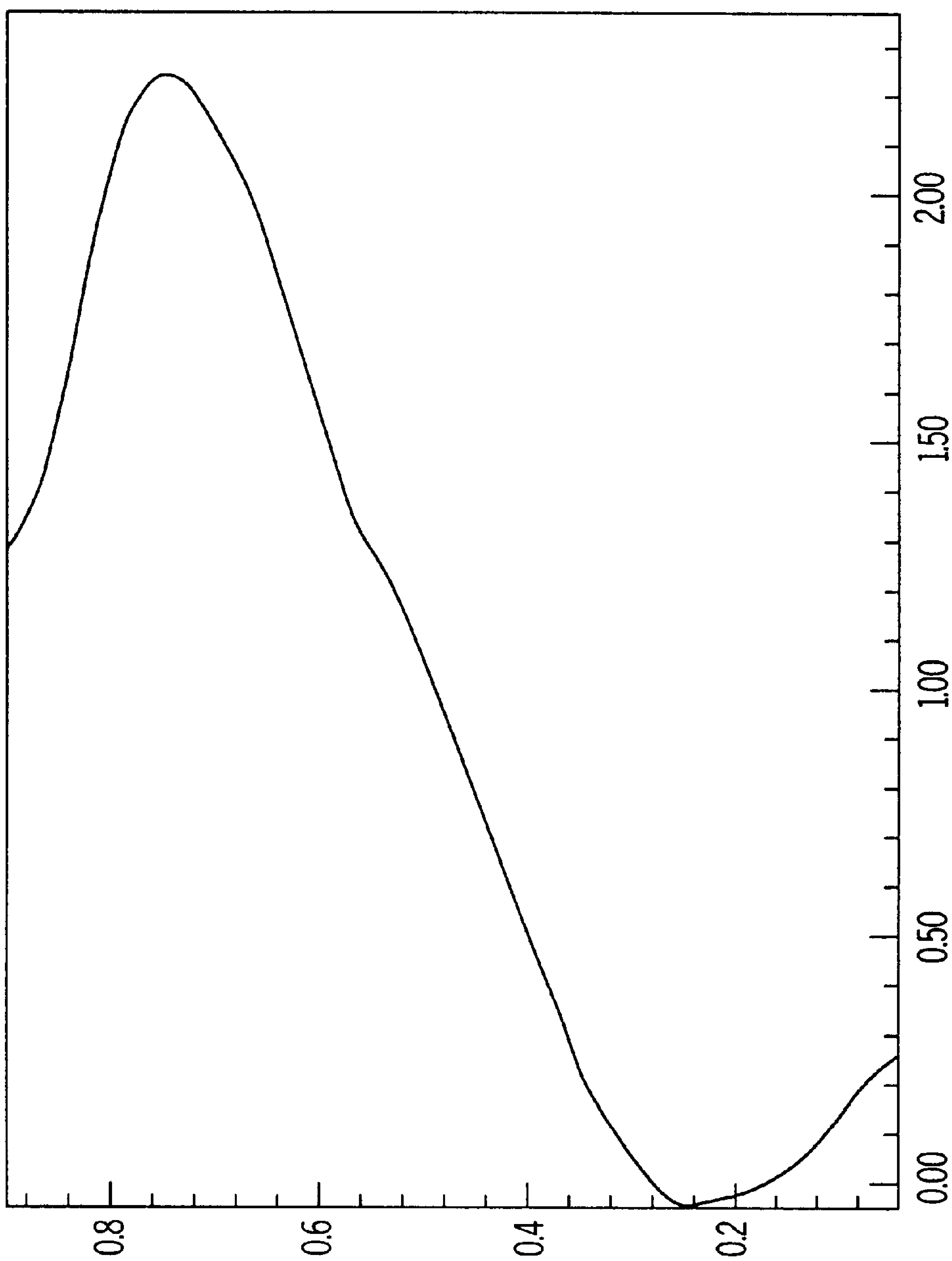

FIG. 8

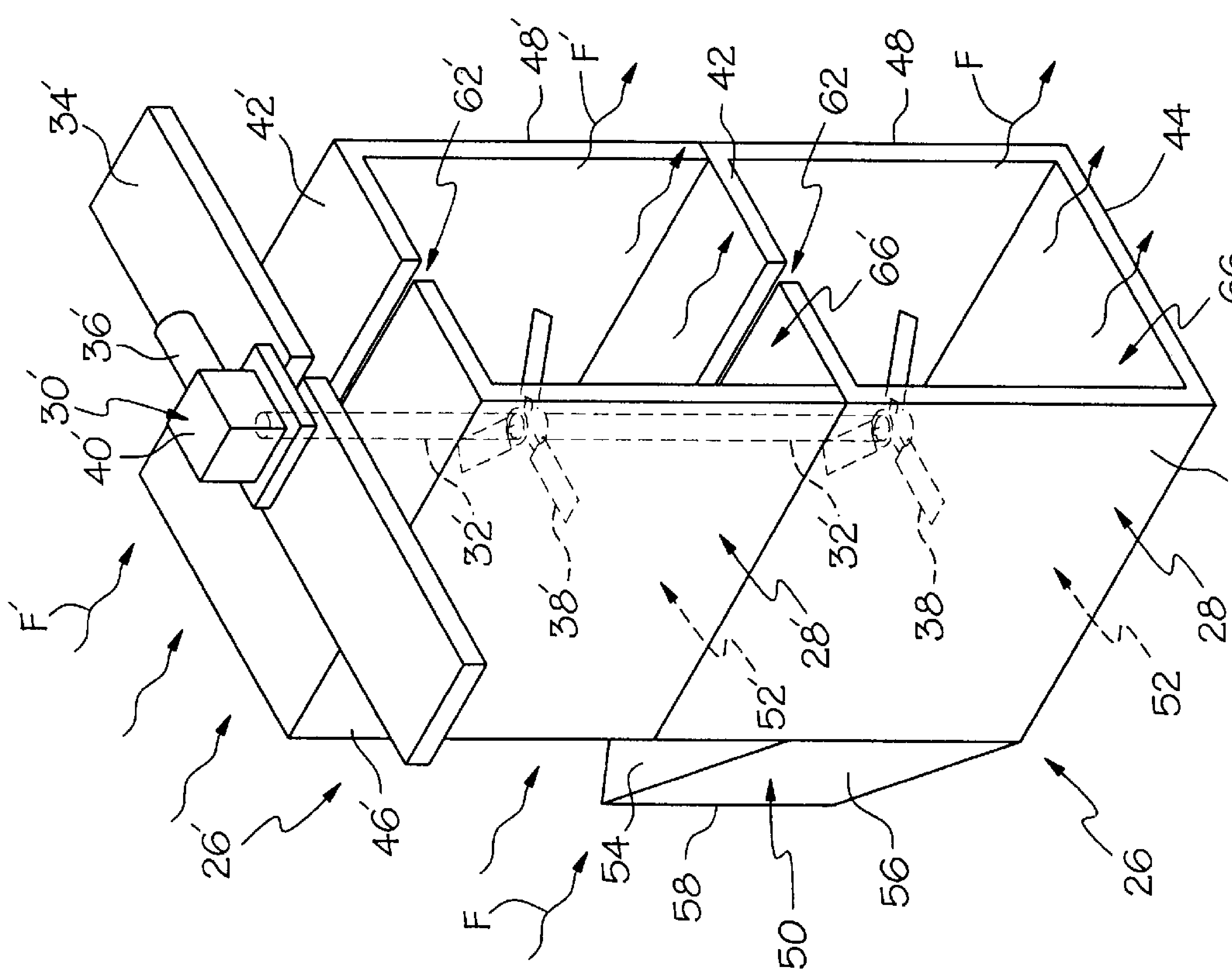

FIG. 10

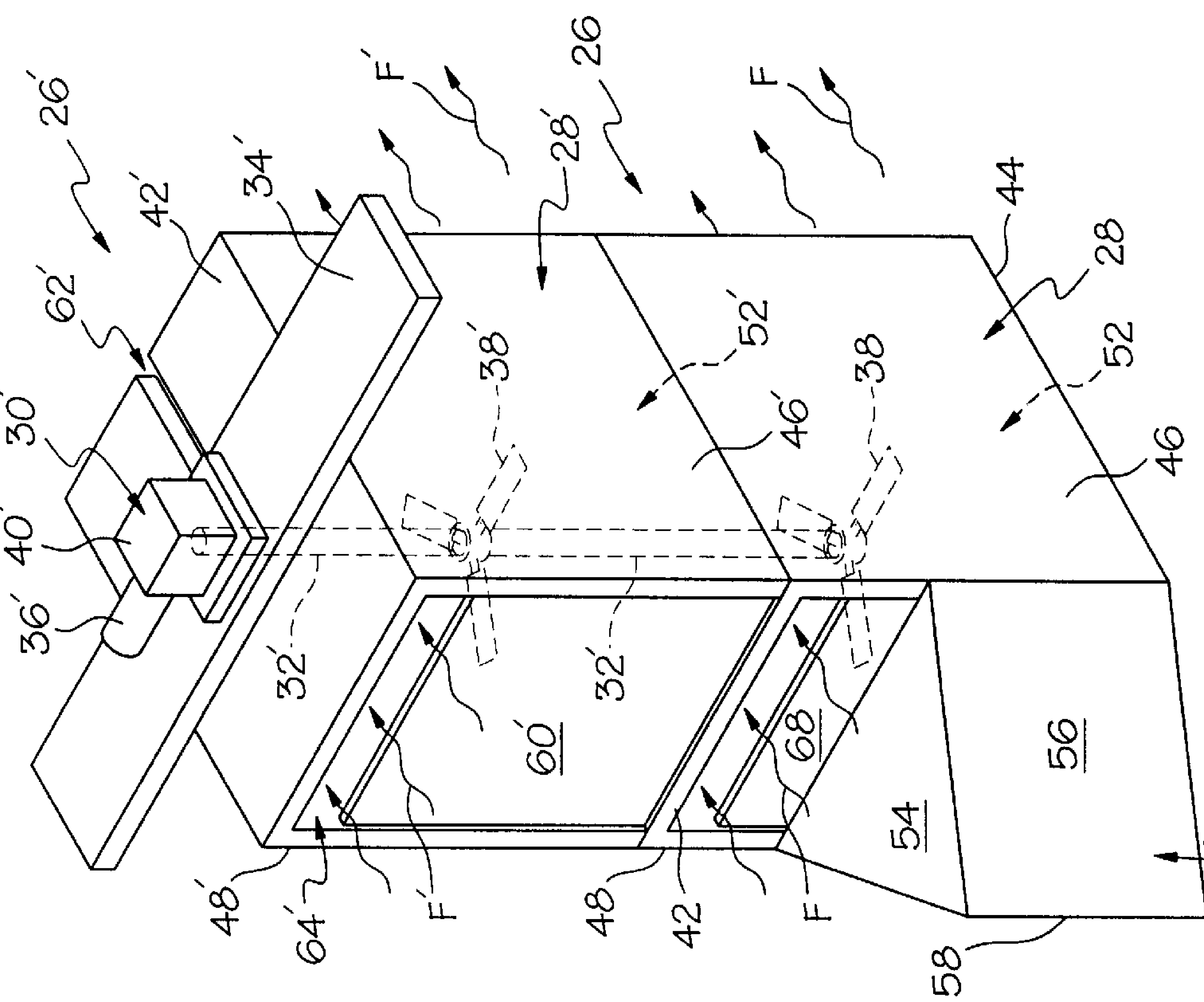

FIG. 9

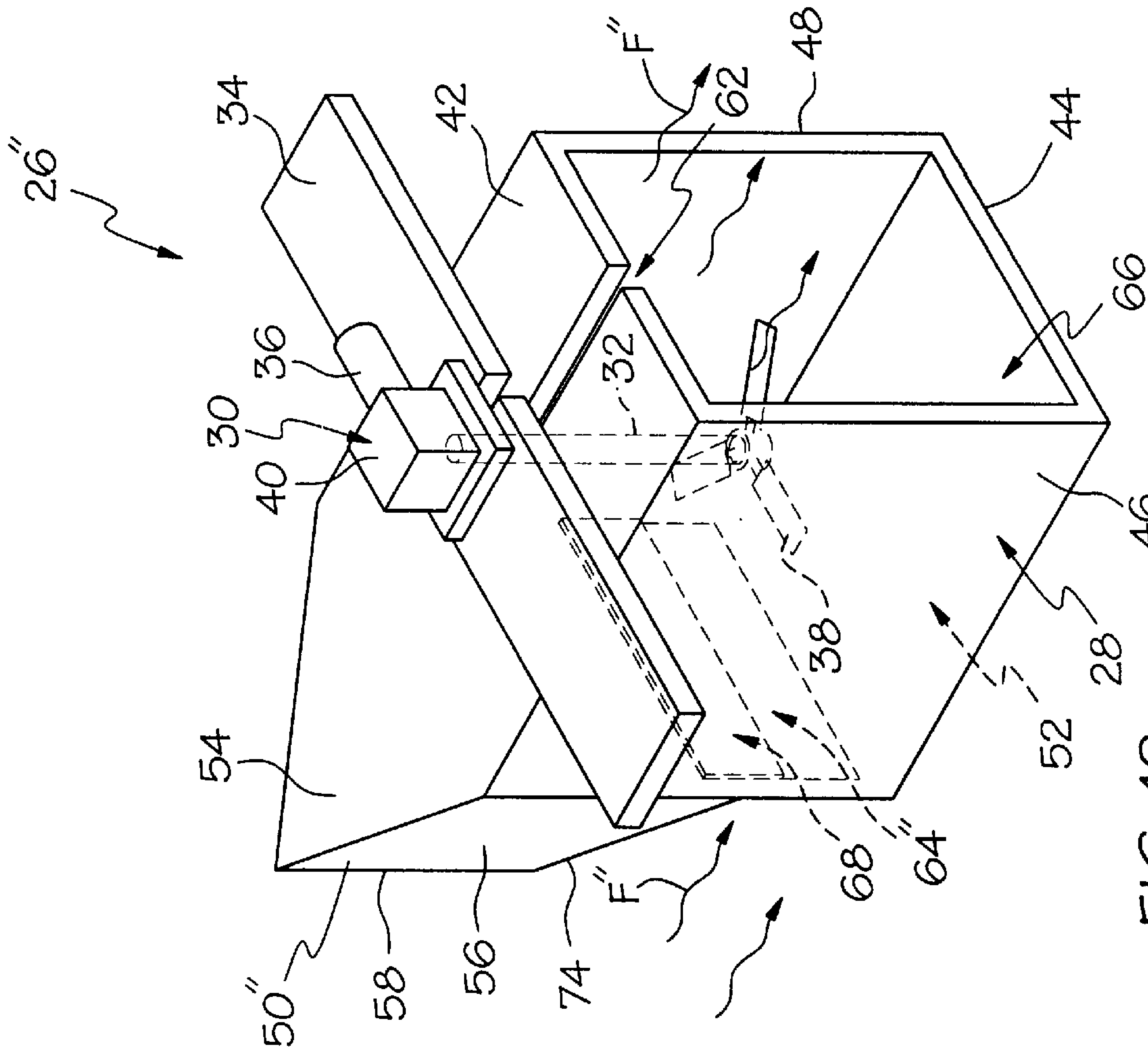
26"
34
42
F"
48
62
44
36
30
40
32
66
46
38
28
54
52
68
64"
50"
58
56
74

FIG. 12

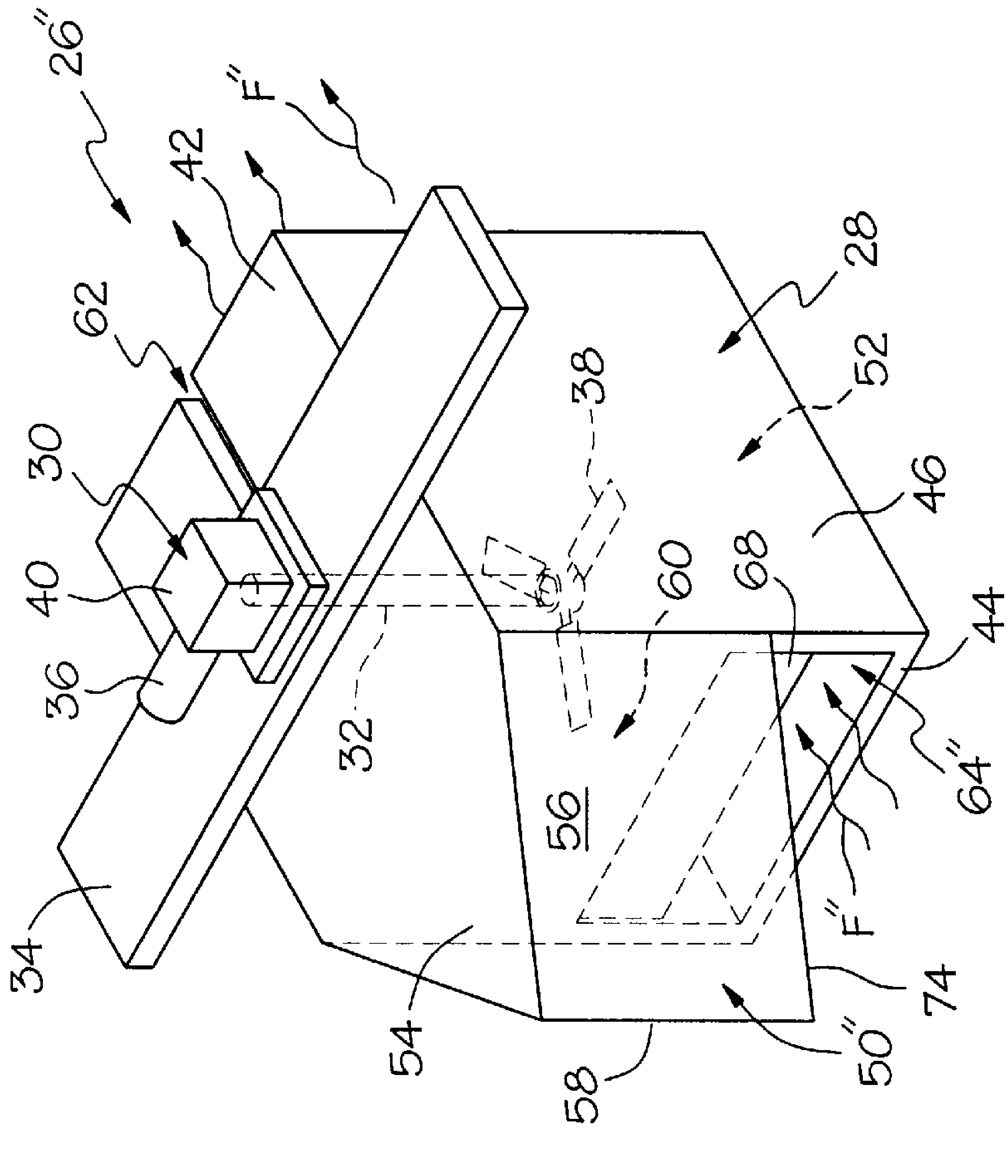
26"
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FIG. 11

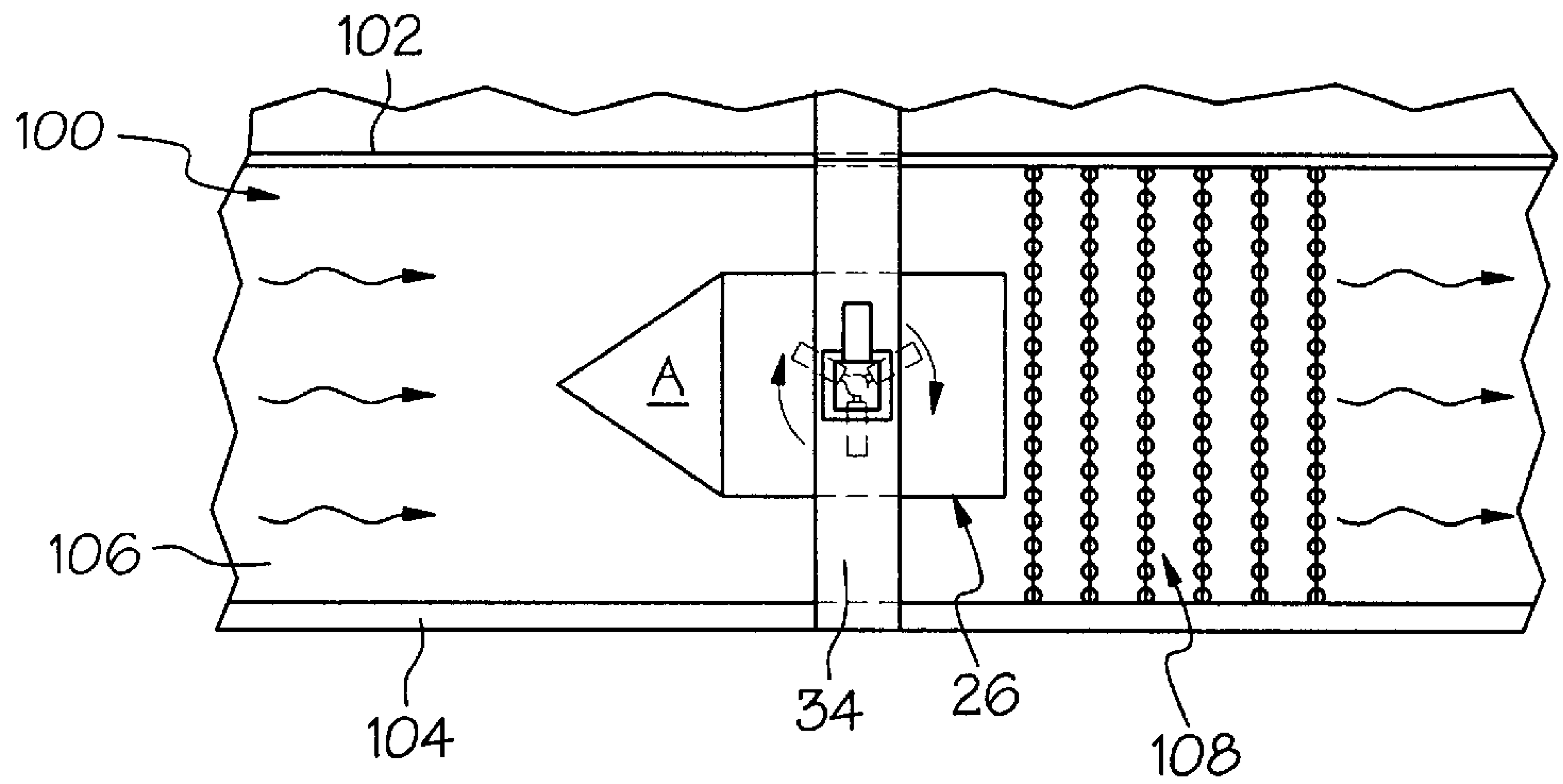

FIG. 13

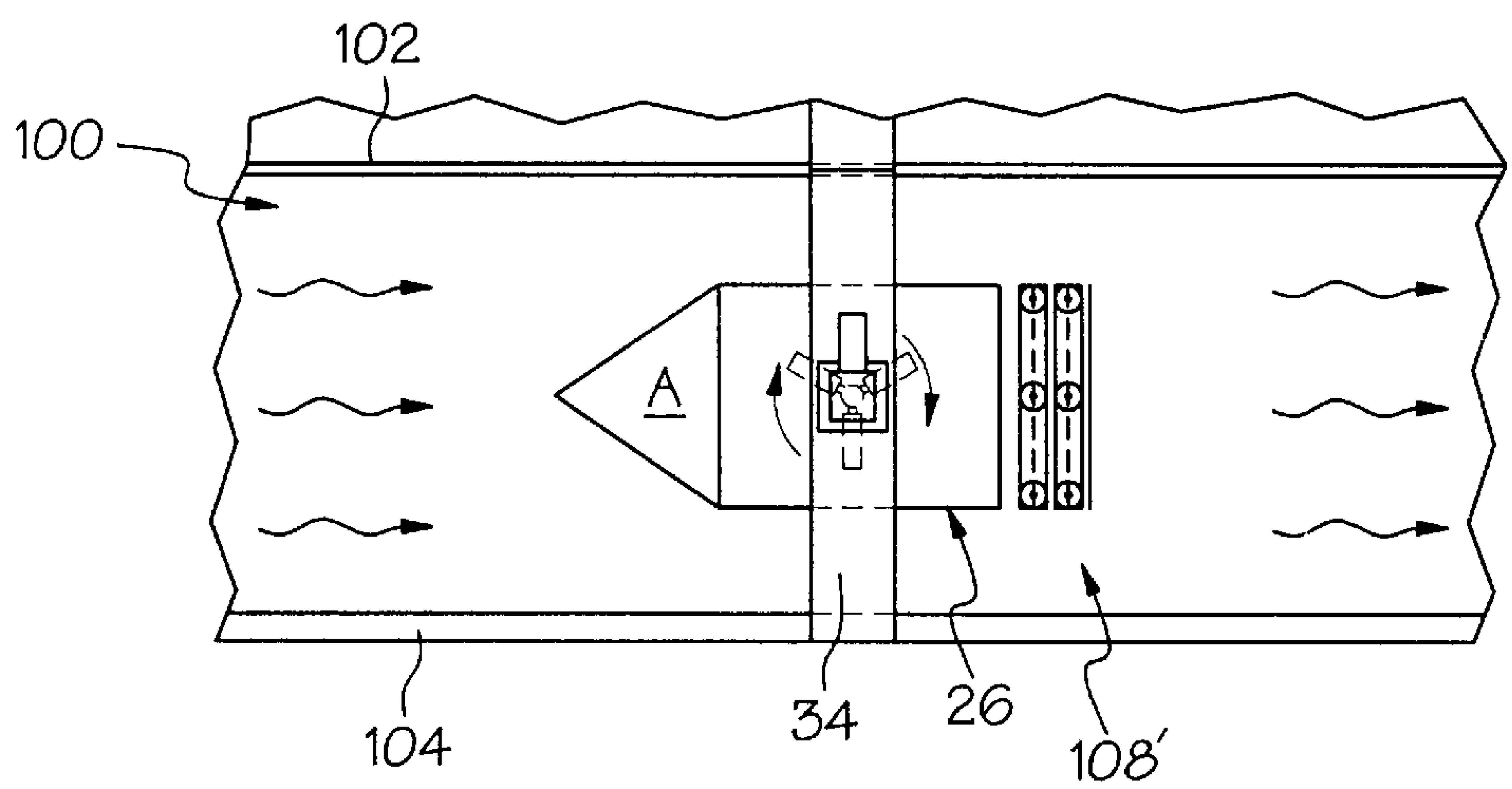

FIG. 14

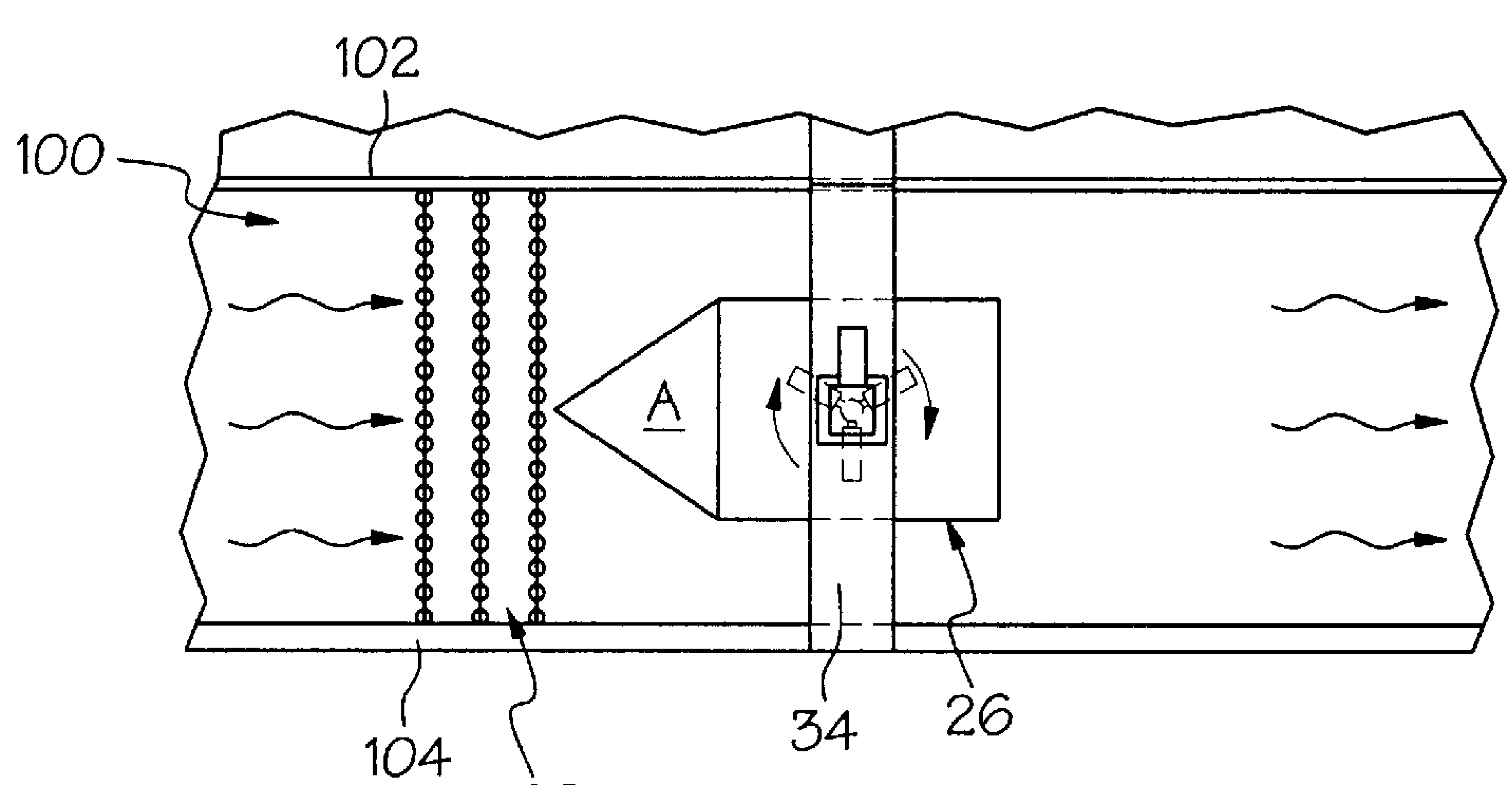

FIG. 16

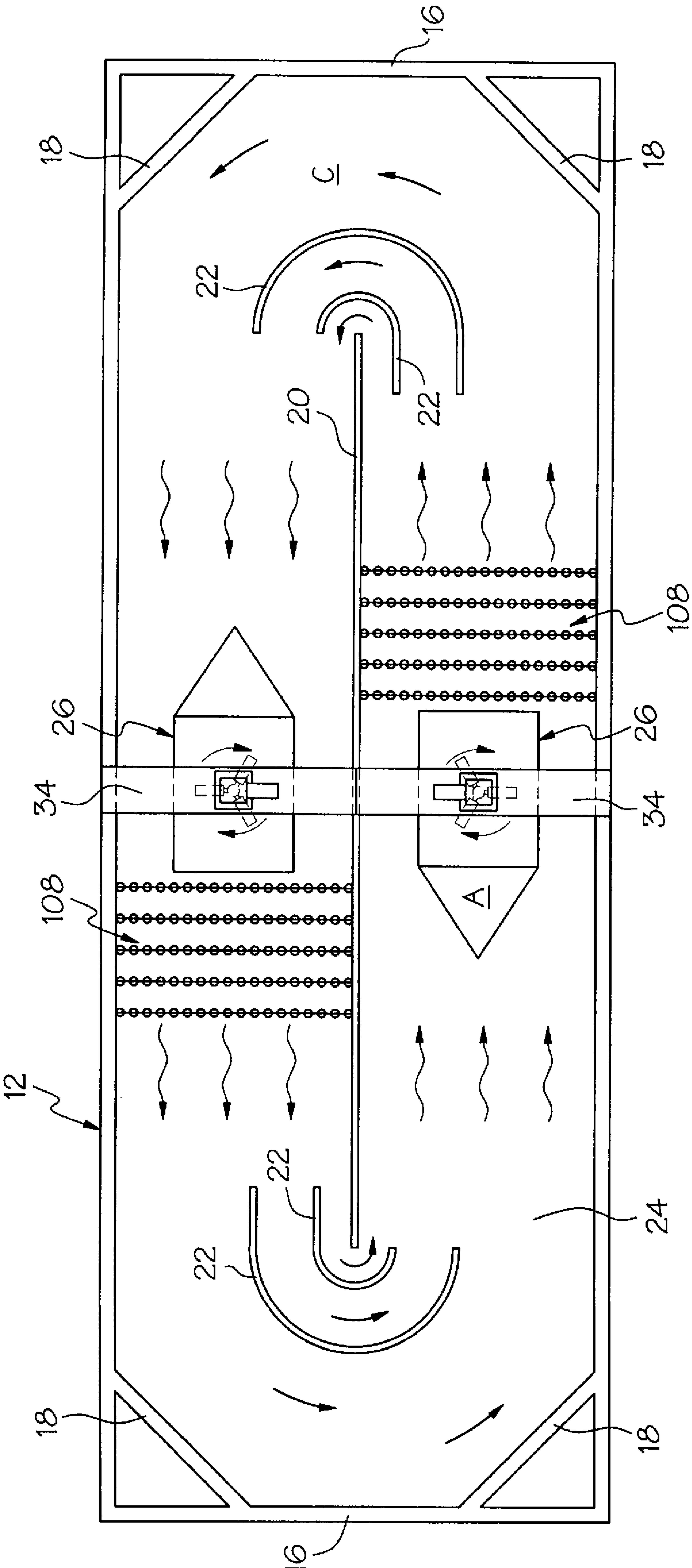

FIG. 15

HORIZONTAL FLOW GENERATION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Ser. No. 08/726,680 filed Oct. 7, 1996 now U.S. Pat. No. 5,803,601.

BACKGROUND OF THE INVENTION

This application is a continuation-in-part of co-pending U.S. application Ser. No. 08/726,680, filed Oct. 7, 1996.

The present invention relates to fluid mixing systems, and more particularly, to a mixing module and method for generating a horizontal fluid flow in a reactor vessel or other flow channel, which vessel or flow channel may include an associated aeration system.

Although horizontal fluid flow is desirable in many fluid mixing systems, the generation of a horizontal fluid flow is especially important in the treatment of water, sewage and like waste liquids in plug flow reactors or oxidation ditches to promote the mixing and agitation of suspended solids. Conventionally, the treatment of water, sewage and like waste liquids in such reactors has utilized multiple side entry or horizontally-oriented turbine agitators. Such agitators require a relatively large amount of horsepower, specific positioning within the reactors and fine adjustments to generate the requisite fluid flow and agitation.

Plug flow reactors have also utilized horizontally-oriented, submersible turbine agitators. Such submersible agitators must be removed from within a plug flow reactor for servicing utilizing various lifting devices. Furthermore, agitators which are entirely submerged require expensive mechanical seals, moisture detectors and housings since the electrical and mechanical components of the agitators are submerged.

In conventional plug flow reactors, the diameter of the impellers on the turbine shafts of the agitators are often limited by the fluid depth of the reactors since the diameter of a side entry or horizontally-oriented turbine extends in a depth-wise direction.

The use of top-entry vertical turbine agitators is known in the art for batch or continuous fluid reactors. For example, U.S. Pat. No. 5,046,856 to McIntire discloses the use of a series of top-entry vertical turbine agitators in a series of tanks wherein at least one of the tanks overflows into another. U.S. Pat. No. 4,566,971 to Reimann et al. teaches the use of a top-entry vertical turbine agitator in a continuous flow-stirred tank. Such top-entry agitators are characterized by mechanicals which are above the liquid level of the associated vessel, and have a vertical shaft extending down into the vessel. However, such "top-entry" vertical turbine agitators have not been used to generate directed, horizontal flow streams.

In reactor vessels or other flow channels which include an aeration system, conventional agitators or mixers must be carefully positioned with respect to the aeration source. For example, horizontal flow losses can be experienced if the mixer or agitator is placed at an upstream position which is close to the aeration source because the aeration source tends to generate a "wall" of gas bubbles. Further, untrue running of the mixer or agitator can occur if the mixer or agitator is placed at a downstream position which is closed to the aeration source due to bubbles being suctioned into the mixer or agitator.

Accordingly, there is a need for a highly efficient fluid mixing system which uses minimal horsepower, provides greater uniformity of velocity profile versus fluid depth and is easily serviced and maintained. There is also a need for a horizontal flow generator which is less sensitive to positioning relative to aeration sources in mixing systems.

SUMMARY OF THE INVENTION

The present invention is a fluid mixing system which includes at least one fluid mixing module and method for generating and maintaining a substantially uniform velocity profile in a fluid circulation system, such as a plug flow reactor, which requires substantially less horsepower than conventional fluid mixing systems without sacrificing mixing efficiency. More particularly, the present invention is a fluid mixing module and method for producing a high velocity mixing regime for large, flat horizontal plug flow reactors which require long fluid detention times.

The fluid mixing module of the present invention employs a top-entry vertically-oriented turbine and a flow generation housing that encloses the turbine impeller and directs fluid pumped by the turbine in a horizontal, downstream direction. The fluid mixing module of the present invention is capable of maintaining high velocities within the plug flow reactor and a relatively constant fluid velocity profile across the reactor's width and depth. Furthermore, a pair of moderately-sized turbine agitators of the present invention generate a sufficient horizontal flow stream to circulate the fluid in a conventionally-sized oxidation ditch or plug flow reactor.

In a preferred embodiment, the top-entry vertical turbine agitator of the present invention includes a drive motor mounted above the reactor fluid level which is a vertically-oriented output shaft that drives an impeller. The housing is shaped to enclose the impeller and includes a partially-open upstream wall, closed side and top walls, and an open downstream side. This housing causes the fluid in the reactor to flow into the housing, where the impeller and housing cooperate to generate a strong downstream fluid flow from the housing sufficient to circulate fluid in a horizontal plug flow reactor or oxidation ditch of conventional size.

The top-entry vertical agitator of the present invention may advantageously be placed in close proximity to an aeration source of a reactor vessel, oxidation ditch or other flow channel. Typically such an aeration source is located at the bottom of the flow channel and releases gas bubbles which flow generally upward. The top-entry vertical agitator may be positioned with the downstream opening of the housing in close proximity to the aeration source such that the horizontal flow exiting the downstream opening passes over the aeration source stripping the gas bubbles from the aeration source before a wall of gas bubbles is formed. Further, the top-entry agitator can be positioned with the upstream side of the housing or nose in close proximity to the aeration source without significant detrimental effect to horizontal flow generation.

Accordingly, it is an object of the present invention to provide a fluid mixing module and method for generating and maintaining a horizontal fluid velocity profile in a reactor vessel; a fluid mixing module that requires relatively low horsepower and energy to mix a plug flow reactor or any large vessel; a fluid mixing module that can be easily serviced in which the drive motor component and mechanicals positioned above the surface of the fluid, thereby eliminating the need for water-tight components; and a fluid mixing module which can be positioned in a flow channel in close proximity to an aeration source.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a top plan view of a preferred embodiment of a fluid mixing system of the present invention, shown mounted within a plug flow reactor;

FIG. 2 is a perspective view taken from the upstream side of the fluid mixing module of FIG. **1**;

FIG. **3** is a perspective view taken from the downstream side of the fluid mixing module of FIG. **1**;

FIG. **4** is a side elevational view in section of the fluid mixing module of the present invention taken at line **4**—**4** of FIG. **1**;

FIG. **5** is a downstream end elevational view in section of the fluid mixing module of the present invention taken at line **5**—**5** of FIG. **1**;

FIG. **6** is a laboratory scale velocity plot of the fluid in a plug flow reactor utilizing the system of FIG. **1** taken at location A of FIG. **1**;

FIG. **7** is a laboratory scale velocity plot of the fluid in a plug flow reactor utilizing the system of FIG. **1** taken at location B of FIG. **1**;

FIG. **8** is a laboratory scale velocity plot of the fluid in a plug flow reactor utilizing the system of FIG. **1** taken at point C of FIG. **1**;

FIG. **9** is a perspective view taken from the upstream side of a second preferred embodiment of a fluid mixing module of the present invention, in which flow generation modules are in a stacked configuration;

FIG. **10** is a perspective view taken from the downstream side of the fluid mixing module of FIG. **9**;

FIG. **11** is a perspective view taken from the upstream side of an alternate embodiment of a fluid mixing module of the present invention;

FIG. **12** is a perspective view taken from the downstream side of the fluid mixing module of FIG. **11**;

FIG. **13** is a top plan view of a flow channel including a fluid mixing module of the present invention positioned upstream of an aeration source;

FIG. **14** is a top plan view of a flow channel including a fluid mixing module of the present invention positioned upstream of an alternative aeration source;

FIG. **15** is a top plan view of reactor vessel including fluid mixing modules positioned upstream of respective aeration sources; and

FIG. **16** is a top plan view of a flow channel including a fluid mixing module of the present invention positioned downstream of an aeration source.

DETAILED DESCRIPTION

The fluid mixing system including fluid mixing modules and method of the present invention is capable of being used generally in any fluid circulation system that requires a directed horizontal fluid flow. As shown in FIG. **1**, in accordance with one preferred embodiment of the present invention, a plug flow reactor, generally designated **10**, includes a tank **12** having side walls **14**, end walls **16** and corner walls **18**. A vertically-oriented divider wall **20** and vertically-oriented turning vanes **22** are disposed within the tank **12**. The tank **12** is filled with fluid **24**, which is typically water with suspended particulates for treatment.

The plug flow reactor **10** further includes a fluid mixing system including two fluid mixing modules **26** which are substantially identical in configuration.

As best shown in FIGS. **2** and **3**, each fluid mixing module **26** includes a housing **28**, a vertically-oriented turbine agitator, generally designated **30**, having a vertically-oriented shaft **32** extending down into the housing **28**, and a support **34** for the agitator **30**. As shown in FIG. **1**, the support **34** spans between a side wall **14** and divider wall **20** of tank **12** to position the fluid mixing module **26** within the tank **12**. The support **34** can be made of any suitable material, preferably steel.

The turbine agitator **30** further includes an agitator drive, preferably an electric motor **36**, which drives an impeller **38** through the shaft **32**. A gear reducer **40** interconnects the motor **36** and shaft **32** in most applications.

The shaft **32** is sized such that the motor **36** and gear reducer **40** are positioned above the surface of the fluid **24**. Consequently, such components of the fluid mixing module **26** as the motor **36** and gear reducer **40** can be serviced and maintained easily without withdrawing the agitator **30** from the fluid **24**. In addition, because the motor **36** is not submerged, the fluid mixing module **26** is capable of utilizing conventional agitator mixer drive designs which avoids relatively costly sealed bearings, seals, and other waterproof mechanical devices normally located below the fluid surface in submersible mixing modules. One commercially available agitator drive for use with a top-entry vertical turbine agitator is the HT agitator drive manufactured by Chemineer, Inc., Dayton, Ohio.

Preferably, the impeller **38** used with the fluid mixing module **26** of the present invention has an axial flow, three blade hydrofoil contour which produces high thrust with relatively low energy input. More preferably, the impeller **38** has a bent blade design. Commercially available impellers **38** are the HE-3 high efficiency impeller and the P-4 Impeller, both manufactured by Chemineer, Inc., Dayton, Ohio. Of course, the use of other impeller designs is within the scope of the present invention.

The housing **28** includes a substantially horizontal top wall **42**, a bottom wall **44**, a pair of substantially vertical, opposing side walls **46**, **48** and a front nose portion, generally designated **50**. The walls **42**–**48** together define an interior **52**, which is sized to receive the impeller **38**. The nose **50** includes an upper wall **54**, forward walls **56**, **58** and a rearward wall **60** (see FIGS. **4** and **5**) which meet to form a triangular prism pointing in an upstream direction. The nose **50** may also take other configurations which, like the illustrated configuration, have a side-to-side width which generally decreases from the downstream end of the nose to the upstream end of the nose. For example, the nose **50** may be cone shaped, the nose **50** may include curved forward walls and a curved or slanted upper wall rather than straight forward walls and a straight and horizontal upper wall, or the nose may be formed from more than four walls. The top wall **42** includes a slot **62** sized to receive the shaft **32**. The side walls **46**, **48** are substantially closed. It should be noted that the bottom wall **44** generally is not needed because the housing **28** preferably rests on the floor **63** of the tank **12** (see FIG. **4**).

The nose **50** is sized relative to the side walls **46**, **48** to form an upstream opening **64**. The housing **28** forms a downstream opening **66**, so that fluid **24** flows into and out of the interior **52** of the housing **28** as represented by the flow arrows F through openings **64** and **66**.

The fluid flow is directed vertically downwardly by the impeller **38**. The flow is redirected to a horizontal direction by the bottom wall **44** and that horizontal flow is forced through the downstream opening **66** as the walls **46**, **48** and **60** prevent flow in the remaining directions. In the embodiment shown in FIGS. **2**–**5**, it is important that the upstream opening **64** be positioned above the impeller **38**, so that flow is drawn through the upstream opening **64** to feed or supply the impeller **38** with a major component of the required volume of fluid needed to generate optimal downstream fluid flow from the housing **28**, and at the same time enhancing the upstream flow of fluid.

The housing **28** is sized relative to the tanks such that a portion of the fluid not entering the housing **28** is directed by the nose portion **50** sidewardly around the housing **28**. The flow of such fluid around the housing **28** conserves energy by maintaining the residual flow through the plug flow reactor **10**. By using the fluid mixing modules **26** of the present invention, no significant back flow is detected around the outside of the housing **28** sidewardly to the front of the housing **28**. In fact, the fluid that flows around the housing **28** mixes with the fluid exiting the housing **28** substantially at or downstream of the downstream opening **66**.

The nose portion **50** can be made from any suitable material, such as steel, plastic or preferably, concrete. It is not necessary to make the material used for the nose portion **50** watertight. The nose portion **50** is sized such that the upper wall **54** guides fluid **24** into the interior **52** of the housing **28** through the upstream opening **64**.

Even though it is desirable to have at least two fluid mixing modules **26** in the plug flow reactor **10**, a single fluid mixing module **26** is generally capable of creating and maintaining a sufficient horizontal flow necessary to maintain the fluid velocity in the plug flow reactor **10**.

The upstream opening **64** in the housing **28** includes a weir **68** which controls the flow of fluid **24** into the housing **28**. The weir **68** includes upper and lower edges or surfaces **70**, **72**, as best shown in FIG. **4**. Fluid **24** flows over the upper edge **70** of the weir **68** when entering the housing **28** through the upstream opening **64**. Preferably, the weir **68** is adjustable in elevation by design or mechanism to open or close the upstream opening **64** to adjust and optimize the horizontal flow stream created by the fluid mixing module **26** in the fluid **24**.

The downstream opening **66** of the housing **28** encompasses substantially the entire area between the top wall **42** and bottom wall **44** (or floor **63**) of the housing **28**, such that the fluid **24** can exit the housing **28** and propel fluid across the entire depth of the fluid in the reactor **10**, as best shown in FIGS. **3**, **4** and **5**.

The operation of the system and fluid mixing module **26**, as best shown in FIG. **1**, is as follows. A tank **12** of a plug flow reactor **10** or oxidation ditch is filled with a fluid **24** for the purpose of treating particulate material suspended in the fluid **24**. The fluid **24** also contains active biological components, such as varieties of bacteria, which break down the particulate organic material. At least one and preferably two fluid mixing modules **26** are placed into the tank **12**, on opposite sides of the divider wall **20** in a relatively straight segment of the tank **12**, and oriented to direct the fluid **24** in a common direction (counterclockwise as shown in FIG. **1**). The modules **26** are actuated and the impellers **38** direct the fluid **24** in the housings **28** downwardly within the interiors **52** of the housings **28**, thus downpumping the fluid **24** from the impellers **38** such that the upstream openings **64** are above the downpumping. The shapes of the housings **28** direct the fluid **24** out the downstream openings **66**.

The fluid **24** exiting the modules **26** is replaced by fluid **24** entering the upstream openings **64** of the modules **26**. As a result of the design of the housings **28**, the fluid flow from the housing **28** is substantially horizontal. For example, in FIG. **6** a laboratory scale velocity plot is taken at point A in FIG. **1**, which is immediately upstream of the upstream opening **64** of one of the modules **26**.

The horizontal fluid flow exiting the housing **28** through the downstream opening **66** has the greatest velocity near the bottom wall **44** of the housing **28** as shown in FIG. **7**, representing a laboratory scale velocity plot taken just outside the downstream opening **66** of the housing **28** at point B in FIG. **1**. In FIG. **7**, the elevation of the impeller **38** is represented by the heavy line.

As shown in FIG. **8**, representing a laboratory scale velocity plot taken at point C in FIG. **1**, the velocity of the horizontal flow is greatest near the surface of the fluid.

FIGS. **7** and **8** establish that a significant top to bottom to top flow pattern is created by using the fluid mixing modules **26** of the present invention. This mixing pattern provides significantly better mixing than known mixing technologies utilized for horizontal plug flow reactors or the like.

The fluid mixing system of the present invention provides the ability to mix much deeper plug flow reactor **10** channels or basins than conventional fluid mixing systems allow. It is believed that the unique discharge path from the top-entry vertical turbine agitator **30** is a key factor in creating this ability to mix much deeper channels or basins. As a result, a reactor of a given size can handle a greater volume of particulate materials with the invention.

When desirable, for example when the depth of the fluid **24** within the plug flow reactor **10**, is relatively large, then two or more fluid mixing modules, a lower unit **26** and an upper unit **26'**, may be stacked in a vertical column, as shown in FIGS. **9** and **10**. In such an embodiment, a single top-entry vertical turbine shaft **32'** extends through the housings **28**, **28'**. Each housing **28**, **28'** substantially encloses a respective impeller **38**, **38'**. In the stacked module embodiment, it is preferable that only the housing **28** of the bottom unit **26** include a nose **50** and that the top wall **42** of the housing **28** of the bottom unit **26** acts as the bottom wall of the housing **28'** of the top unit **26'**.

As shown in FIGS. **11** and **12**, in an another alternate embodiment of the invention, the nose **50"** is sized relative to the side walls **46**, **48** of the housing **28** to form an upstream opening **64"**, so that fluid **24** flows into and out of the interior **52** of the housing **28** as represented by the flow arrows F" through openings **64"** and **66**. Preferably, the nose **50"** is substantially identical in configuration to nose **50**, as shown in FIGS. **1–5**, with the addition of a lower wall **74**.

The fluid flow is directed vertically upwardly by the impeller **38**. The flow is redirected to a horizontal direction by the top wall **42** and that horizontal flow is forced through the downstream opening **66** as the walls **46**, **48** and **60** prevent flow in the remaining directions. In the embodiment shown in FIGS. **11** and **12**, it is important that the upstream opening **64"** be positioned below the impeller **38**, so that flow is drawn through the upstream opening **64"** to feed or supply the impeller **38** with a major component of the required volume of fluid needed to generate optimal downstream fluid flow from the housing **28**, and at the same time enhancing the upstream flow of fluid.

To achieve the best results, the upstream openings **64**, **64'** and **64"** must be upstream of the fluid discharge from the impellers **38** or **38'**.

The fluid mixing system of the present invention creates a velocity profile in the fluid with respect to the depth of the plug flow reactor that is substantially uniform. The fluid mixing system of the present invention utilizes torque rather than horsepower to generate fluid velocity. As a result, plug flow reactors using the fluid mixing system of the present invention can be effectively mixed with about one-tenth the amount of horsepower required for submersible mixing systems, such as submersible agitators, to mix a similar plug flow reactor. Positioning turning vanes **22** or the like within the tank **12** of a plug flow reactor **10** in the curves of the tank **12**, as shown in FIG. **1** is desirable to assist in maintaining high velocities within the reactor and a relatively uniform velocity profile in the fluid across the reactor's width and throughout its depth.

The mounting of an aeration source in the bottom of the tank of the plug flow reactor or other flow channel immediately downstream of the fluid mixing module will increase oxygenation in the fluid which gets depleted as it flows throughout the plug flow reactor or oxidation ditch. This is accomplished because the increase in fluid flow increases the shearing effect on the gas bubbles generated from the grid of the aerator. For example, reference is made to FIGS. **13** and **14** which show a three-sided flow channel **100** formed by side walls **102**, **104** and bottom wall **106**. A fluid mixing module **26** is positioned along flow channel **100** to aid horizontal fluid flow generally indicated by the arrows. In FIG. **13** an aeration source **108** is positioned at the downstream side of mixing module **26** in close proximity to the downstream opening of the mixing module **26**. In FIG. **14** an aeration source **108'** is likewise positioned at the downstream side of mixing module **26** in close proximity to the downstream opening of the mixing module **26**. Aeration source **108** may be, for example, a plurality of fine bubble diffusers or membrane diffusers while aeration source **108'** is more representative of a manifold type aeration source. Other types of porous and non-porous diffusers could likewise be utilized as aeration sources in conjunction with the mixing module of the present invention. Although use of aeration sources is generally known, placement of such aeration sources in close proximity to the downstream side of horizontal flow generating devices has previously been avoided. Advantageously, the mixing module **26** generates a large enough horizontal fluid flow that shearing forces effectively strip gaseous bubbles from the aeration source **108**, **108'** such that the gaseous bubbles are immediately mixed with the liquid flow stream rather than rising up to form a bubble "wall" as has commonly occurred in the past. In order to achieve this desired bubble stripping effect it is preferred that the horizontal distance between the downstream opening of the mixing module **26** and the upstream side or edge of the aeration source **108**, **108'** be within a range of from about ¼ to about ½ the diameter of the impeller of the mixing module **26**. For example, in a mixing module including an eighty inch diameter impeller the preferred range would be from about twenty inches to about forty inches. As used herein, the downstream opening of the mixing module **26** is considered to be in close proximity to the aeration source **108**, **108'** if the horizontal distance between the downstream opening of the mixing module and the upstream side or edge of the aeration source is within about ½ the diameter of the impeller of the mixing module or closer.

The bubble stripping effect is enhanced because the mixing module of the present invention not only provides a high horizontal flow rate but also provides such high flow rate near the bottom of the flow channel **100**. Accordingly, it is preferred to use a mixing module embodiment of the types shown in FIGS. **2** and **3** or **9** and **10**, although the embodiment shown in FIGS. **11** and **12** could also be used in conjunction with aeration sources. Referring to FIG. **15**, it is noted that the mixing module may be used in conjunction with the plug flow reactor **10** of FIG. **1** where multiple aeration sources **108** are positioned downstream of the mixing modules **26**.

Advantageously, the mixing module of the present invention may also be positioned immediately downstream of the aeration source as shown in FIG. **16**. In such cases due to the high flow created around the mixing module housing aeration bubbles will tend to flow around the housing to mix with the high horizontal flow exiting the downstream opening of the mixing module **26**. Other aeration bubbles may be pulled into the upstream opening and pass by the impeller of the mixing module. In such systems the aeration source **108**, **108'** may be placed immediately in front of the nose of the mixing module **26** and might also extend partially along the sides of the mixing module **26**. Further, a fine bubble aeration source may even be placed immediately in front of the upstream opening of the mixing module housing so that substantially all of the gas bubbles pass by the impeller of the mixing module. In such a system, the fine bubble aeration source could be placed on, adjacent, or integrated with the upper wall or surface of the nose portion of the mixing module in mixing module embodiments where the upstream opening is above the nose portion of the housing, or the fine bubble aeration source could be placed along the bottom surface of the flow channel directly in front of the upstream opening in mixing module embodiments where the upstream opening is positioned below the nose portion of the housing. The high flow capabilities of the mixing module of the present invention allow it to work effectively even when the gas bubbles are directed into the upstream opening of the housing. This represents a substantial distinction and improvement over conventional systems incorporating aeration.

Although use of the mixing module **26** of the present invention has been described in a preferred form as being inclose proximity to the aeration source **108**, **108'**, it is recognized that the mixing module **26** could likewise be placed further from the aeration source **108**, **108'**.

By way of example, a comparison of the fluid mixing module of the present invention and a conventional fluid mixing apparatus is provided. In a plug flow reactor tank having a depth of 20 feet and a chamber width of 40 feet, the fluid mixing module of the present invention can employ an impeller having a diameter as large as 12 feet which in operation typically rotates at 30 to 37 rpm or less to effectively drive the plug flow reactor. In the same plug flow reactor tank, a conventional horizontally-oriented turbine agitator can only use an impeller having a diameter in the range of about 30 inches to about 87 inches which in operation typically rotates at about 150 rpm or above to effectively drive the plug flow reactor. The energy conservation evidenced by the use of the fluid mixing module of the present invention is substantial.

Preferably, the housing **28** is made from a suitable material such as concrete, stainless steel, coated steel, rust-resistant steel or combinations thereof. Those skilled in the art will appreciate that other suitable materials are not outside the scope of the present invention.

Having described the invention in detail and by reference to the drawings, it will be apparent that modifications and variations are possible without departing from the scope of the invention as defined in the following claims.

What is claimed is:

1. A horizontal flow generation system comprising:

a liquid containing channel;

a drive motor having a substantially vertically-oriented, rotatable output shaft extending downward into said liquid containing channel;

an impeller mounted on said output shaft within the liquid containing channel;

a housing enclosing said impeller and having an upstream and a downstream opening for entrance and egress, respectively, of liquid, wherein rotation of said impeller causes liquid to enter said housing through said upstream opening substantially perpendicular to said output shaft and be propelled through said downstream opening substantially perpendicular to said output shaft; and

an aeration source positioned along a bottom of said liquid containing channel, wherein a horizontal distance between said downstream opening of said housing and an upstream side of said aeration source is within about ½ of a diameter of said impeller.

2. The horizontal flow generation system of claim **1** wherein a horizontal distance between said downstream opening of said housing and an upstream side of said aeration source is within a range of about ¼ to ½ of a diameter of said impeller.

3. The horizontal flow generation system of claim **1** wherein said housing includes a nose portion positioned below said upstream opening of said housing, said nose portion having a side-to-side width that generally decreases from a downstream end of said nose portion to an upstream end of said nose portion.

4. The horizontal flow generation system of claim **1** wherein said flow channel comprises part of a tank which includes outer walls and a central partition.

5. The horizontal flow generation system of claim **1** wherein said aeration source is positioned downstream of said downstream opening of said housing.

6. The horizontal flow generation system of claim **5** wherein said downstream opening of said housing is positioned in close proximity to said aeration source.

7. The horizontal flow generation system of claim **6** wherein said downstream opening of said housing and an upstream side of said aeration source is within a range of about ¼ to ½ of a diameter of said impeller.

8. A horizontal flow generation system comprising:

a liquid containing channel;

a drive motor having a substantially vertically-oriented, rotatable output shaft extending downward into said liquid containing channel;

an impeller mounted on said output shaft within the liquid containing channel;

a housing enclosing said impeller and having an upstream and a downstream opening for entrance and egress, respectively, of liquid, wherein rotation of said impeller causes liquid to enter said housing through said upstream opening substantially perpendicular to said output shaft and be propelled through said downstream opening substantially perpendicular to said output shaft, wherein one of said upstream opening and said downstream opening is positioned above said impeller and the other of said upstream opening and said downstream opening is positioned below said impeller, an interior of said housing being substantially open between said upstream opening and said downstream opening;

an aeration source positioned within said liquid containing channel; and

wherein said housing includes a nose portion positioned alongside said upstream opening of said housing, said nose portion having a side-to-side width that generally decreases from a downstream end of said nose portion to an upstream end of said nose portion.

9. The horizontal flow generation system of claim **8** wherein said flow channel comprises part of a tank which includes outer walls and a central partition.

10. The horizontal flow generation device of claim **8** wherein liquid enters through said upstream opening of said housing in a plane substantially perpendicular to said outputs shaft and liquid is propelled through said downstream opening in a plane substantially perpendicular to said output shaft.

11. The horizontal flow generation device of claim **8** wherein said aeration source is located upstream of said upstream opening of said housing.

12. The horizontal flow generation device of claim **11** wherein said upstream opening of said housing is positioned above said nose portion and said aeration source is positioned above said nose portion.

13. A horizontal flow generation system comprising:

a liquid containing channel;

a drive motor having a substantially vertically-oriented, rotatable output shaft extending downward into said liquid containing channel;

an impeller mounted on said output shaft within the liquid containing channel;

a housing enclosing said impeller and having an upstream and a downstream opening for entrance and egress, respectively, of liquid, wherein rotation of said impeller causes liquid to enter said housing through said upstream opening and be propelled through said downstream opening;

an aeration source positioned within said liquid containing channel; and

wherein said housing includes a nose portion positioned alongside said upstream opening of said housing, said nose portion having a side-to-side width that generally decreases from a downstream end of said nose portion to an upstream end of said nose portion;

wherein said aeration source is located upstream of said upstream opening of said housing; and

wherein said upstream opening of said housing is positioned above said nose portion and said aeration source is positioned above said nose portion.

14. A liquid mixing assembly for generating horizontal flow when submerged in a liquid containing channel, comprising:

a drive motor having a substantially vertically-oriented, rotatable output shaft;

a first impeller mounted on said output shaft;

a housing enclosing said impeller and having an upstream and a downstream opening for entrance and egress, respectively, of liquid, wherein rotation of said impeller causes liquid to enter said housing through said upstream opening in a plane substantially perpendicular to said output shaft and be propelled through said downstream opening in a plane substantially perpendicular to said output shaft, wherein one of said upstream opening and said downstream opening is positioned above said impeller and the other of said upstream opening and said downstream opening is positioned below said impeller, an interior of said housing being substantially open between said upstream opening and said downstream opening; and

wherein said housing includes a nose portion positioned alongside said upstream opening of said housing, said nose portion having a side-to-side width that generally decreases from a downstream end of said nose portion to an upstream end of said nose portion.

15. The liquid mixing assembly of claim **14** further comprising an aeration source positioned such that egress flow from said housing comprises an aerated liquid.

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